RESEARCH DEPARTMENT

THE SUBJECTIVE SIGNIFICANCE OF SECONDARY REVERBERATION

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C.L.S. Gilford, M.Sc., Ph.D., F.Inst.P., M.I.E.E.
D.K. Jones, B.Sc., A.Inst.P., A.M.I.E.R.E

D. Maurice
for Head of Research Department

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SUMMARY

Subjective tests have been carried out to determine the level of excitation at which a resonance of long decay time becomes audible on speech in a typical talks studio. It was concluded that speech would be acceptably free from serious colouration due to the resonance, provided that the sound pressure level at the microphone due to the resonance is at least 30 dB below that arising from normal reverberation.

1. INTRODUCTION

In carrying out acoustic tests on studios it is convenient to record the time variation of sound pressure during the free decay of sound, using a logarithmic scale of pressure. A statistically uniform (exponential) decay process will then appear as a sloping straight line, with irregular perturbations. Any curvature or change in the general slope or a logarithmic display indicates the existence of two or more modes of free decay with different time-constants.

In the testing of the talks studios in the new Broadcasting House, Llandaff, systematic double slopes were found over a wide range of frequency in the bass. These double slopes could be heard as low-frequency colourations at several frequencies and it was necessary to devise economical methods of cure.

They were shown[1] to be caused by lightly-damped vibrations of the suspended ceiling structure. These could be reduced to any desired extent by stiffening members, but as the operation was expensive, steps were taken to find out as accurately as possible how little stiffening needed to be introduced to make speech acceptable.

The method used was to synthesise in the laboratory double decays similar to those under investigation and then to carry out systematic listening tests using Research Department and other personnel accustomed to monitoring the reproduction of speech.

2. EXPERIMENTAL WORK

Electronic means were used to synthesise double decays, such as that illustrated in Figure 1. The first portion, AB, of the decay represents the decay of room modes with a short reverberation time. At a level of above 30 dB below initial excitation, the decay changes slope to one characteristic of the decay of the ceiling resonance, (BC). The curve in Fig. 1 has a first slope corresponding to a reverberation time of 0·35 sec. and a second slope corresponding to 1·40 sec, the times used in the subjective experiment to typify the reverberation times of a talks studio and of a ceiling resonance respectively.

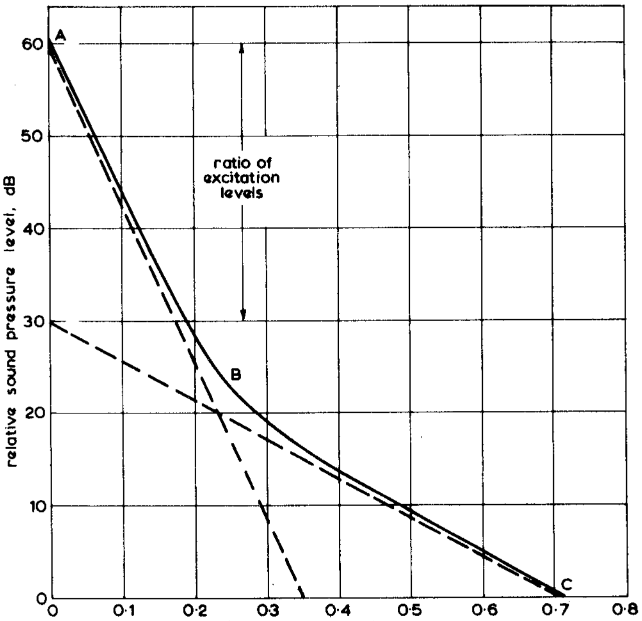

Fig. 1 - Idealized double-slope decay

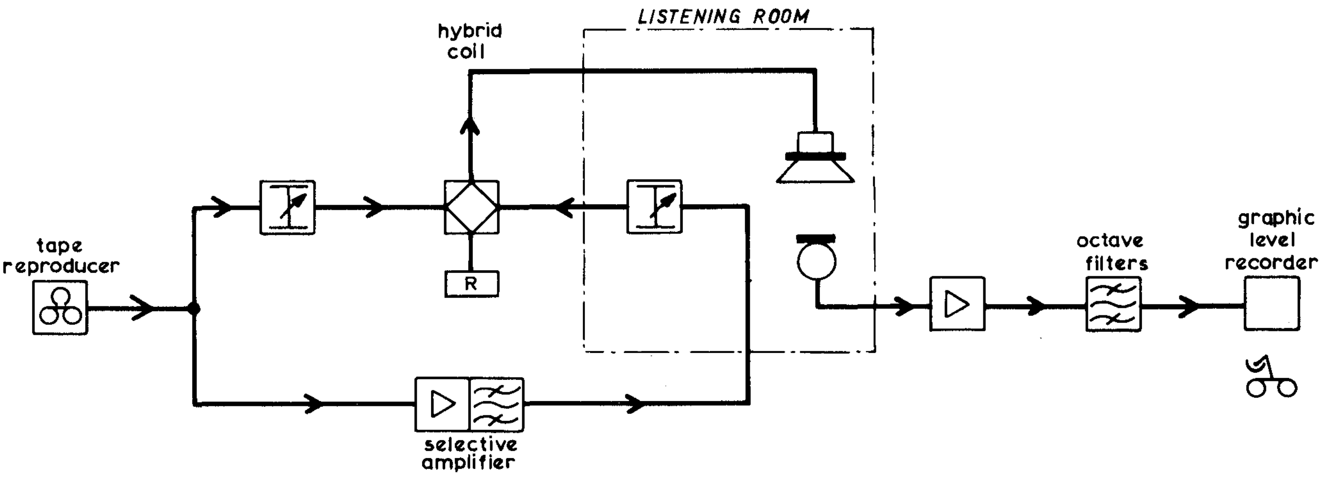

Fig. 2 - Testing and measurement chain

Fig. 2 is a block diagram of the apparatus. Samples of speech recorded in a free-field room were played into two parallel channels, one containing a selective amplifier tuned to a low audio-frequency, the other containing only an attenuator for the initial setting of levels. The direct and selective channels were then combined by a hybrid coil and fed to a loudspeaker in a listening room with a reverberation time of 0·35 sec. in which the subject was seated. The positive feedback in the selective amplifier was set to give a decay time of 1·4 sec. The test subject was provided with an attenuator with which he adjusted the level of the selective channel until it produced a colouration which was just noticeable in the presence of the speech. This was noted and the experiment was then repeated for each of the other samples of speech.

The relative level of the two channels as heard in the room was determined afterwards by playing the recording back into the studio and feeding the microphone output through an octave band-pass filter to a level recorder. This was repeated with the direct sound faded out, thus enabling the relative levels to be determined from the paper traces made by the level recorder, for each of the speech samples. The results are shown in the table in the next section. This measurement, in conjunction with the attenuator settings chosen by the subjects, enabled the acceptable level of the colouration, whose presence was indicated by the second slope, to be determined.

3. RESULTS

The table below gives the average ratio of speech level to just acceptable colouration level as determined by the group of subjects. Eight samples of speech with different voices were used and selective amplifier frequencies of 125 Hz, 175 Hz, 210 Hz and 220 Hz were used in succession.

TABLE 1

Signal/Colouration Ratio Determined From Subjective Tests

colouration frequency (resonance frequency)	voice A	B	C	D	E	F	G	H	mean
	signal/colouration ratio, dB								
125 Hz (7 subjects)	29	28	27	32	32	33	31	29	30
175 Hz (8 subjects)	21	25	25	29	28	27	27	27	26
210 Hz (7 subjects)	34	35	33	36	36	39	35	28	34
220 Hz (9 subjects)	39	42	42	40	44	-	38	37	40

It will be noticed that there is a rise in the mean acceptable signal/colouration ratio with increase of frequency, though the 175 Hz results are below the general trend; the reason for this was not ascertained.

The acceptable levels of colouration at any frequency vary by amounts up to 8 dB between different voices. This is to be expected, as individual voices are characterised by their fundamental and formant frequencies, and a particular colouration will be most noticeable on a voice having the resonance frequency as a predominant component. For this reason the order of severity of colourations at the four test frequencies varies from voice to voice. The 175 Hz colouration, however, is the least noticeable on all voices.

As a condition of acceptance in the Llandaff studios, a figure of 30 dB was chosen as likely to give acceptable results under most conditions.

4. CONCLUSIONS

The tests described in this report show that a second slope in a sound decay may be audible if the amplitude of excitation of the mode with which it is associated is 28 dB or less below that of the room excitation. The ratio increases with increase of frequency in the region of interest but varies quite widely with the characteristics of the speaker's voice. It was decided to regard studios as acceptable if the measured ratio was better than 30 dB.

5. REFERENCE

1. Preliminary acoustic tests in the New Headquarters, Wales (Baynton House, Cardiff). BBC Research Department Report No. B-089/5, Serial No. 1966/49.

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